AD-A283 385

[RE]PORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

[...]ted to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, [...]ewing the collection of information. Send comments regarding this burden estimate or any other aspect of this [...]urden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson [...]Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

[2. REPO]RT DATE

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE

A Mechatronics Framework for High Precision Machining

5. FUNDING NUMBERS

Grant #
N00014-94-1-0235

6. AUTHOR(S)

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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8. PERFORMING ORGANIZATION REPORT NUMBER

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AUG 1994
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9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

ONR
Ballston Tower One
800 North Quincy Street
Arlington, VA 22217-5660

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The development of a new mechantronic tool holder system that is capable of fast and precise local tool adjustments based on sensory feedbacks is proposed. Central to this development is the use of magnetic servo levitation for driving the tool as well as for measuring tool forces. To control the device, a Neural Network based model identifier and H-∞ based high servo stiffness scheme will be used. The device will be capable of a high bandwidth tool adjustment (up to 300Hz) and long range motion (1 mm). This long range feature is particularly desirable for fabricating non-rotationally symmetric surfaces considering that conventional piezo-electric driven systems average an order of magnitude smaller ranges.

Since the beginning of the project 2 months ago, initial efforts have focused on sizing the electromagnets such that sufficient force can be generated while minimizing the volume of the actuator.

14. SUBJECT TERMS

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

SPd

94-25768

DTIC QUALITY INSPECTED 1

94 8 09 049

Progress Report

to

Office of Naval Research

A Mechatronics Framework For High Precision Machining

Covering Period
January 1994 - April 1994

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A MECHATRONICS FRAMEWORK FOR HIGH PRECISION MACHINING

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The goal of this project is to develop and construct a Fast Tool Servo (FTS) System using an Electromagnetic Force Actuator. The design objectives for the FTS are (a) a range of 0.6 - 1.0 millimeters, (b) resolution on the order of nanometers, and (c) 300 Hz bandwidth.

Initial efforts have focused on sizing the electromagnets such that sufficient force can be generated while minimizing the volume of the actuator. With a knowledge of the moving mass and its acceleration as a function of time, the required actuator forces can be established. However, since the actual operating conditions which the actuator will encounter are difficult to predict, sinusoidal motion is often used as a simplified design metric. Given that the force required for sinusoidal motion is a function of the moving mass, the displacement amplitude, and the frequency, the required force can be estimated.

$$F = m\,\ddot{x} = -\,m\,X_{max}\,\omega^2 \sin(\omega t) \tag{1}$$

where "m" is the moving mass, "$\ddot{x}$" is the acceleration, "X_{max}" is the maximum displacement amplitude, "ω" is the circular or angular frequency of the motion, and "t" is time.

The theoretical attractive force generated by an electromagnet is given by the following expression:

$$F = \frac{\mu_0\, N^2\, i^2\, l\, w}{4\, g^2} \tag{2}$$

where "μ_0" is the permeability constant, "N" is the number of turns of coil wire, "i" is the current through the coil wire, "l" is the length of the pole area (i.e., the end area of the center leg or half of the end area of the three legs), "w" is the width of the pole area, and "g" is the gap between the "E" and "I" laminations (see Figure 1).

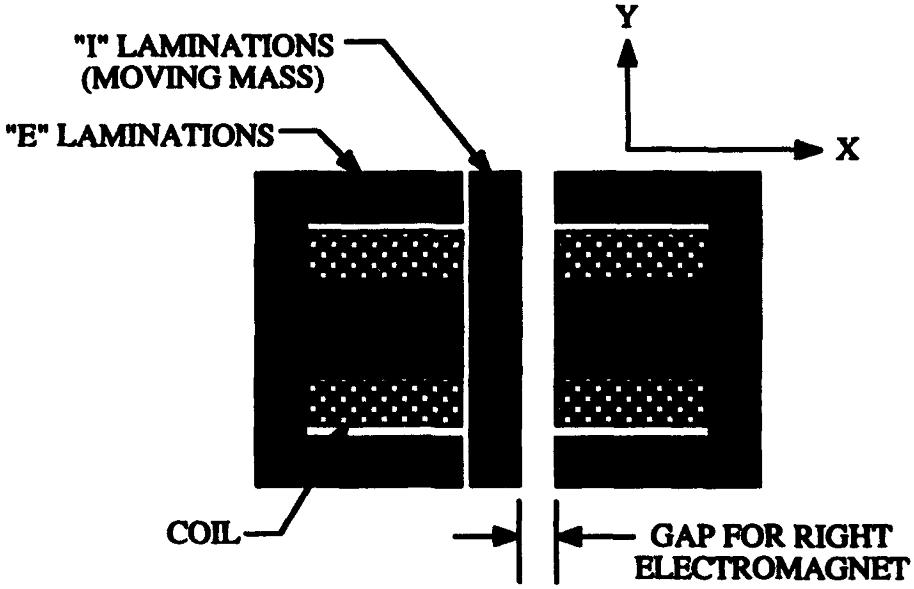

***Figure 1:** "Pull-Pull", Two-Electromagnet System.*

For sinusoidal operation of the "pull-pull", two-electromagnet system shown in Figure 1, the maximum required positive force (i.e., the attractive force exerted on the moving mass by the right electromagnet) occurs when the moving mass is located at its most negative position (i.e., the leftmost position). However, the magnitude of this positive force is a minimum at this most negative position. To compensate for this potential force defficiency, flexures will be investigated for use in supplementing the electromagnetic force at large gaps (see Figure 2). The restoring force of a flexure(s) could assist the electromagnet in pulling the moving mass back to the center position (see Figure 3). Although the electromagnet would have to overcome the flexure force in order to continue pulling the moving mass past center, it can be seen in Figure 3 that the electromagnet would be capable of generating more force in this positioning range because of the reduced gap. The flexures could also serve as a bearing system to guide the motion of the moving mass.

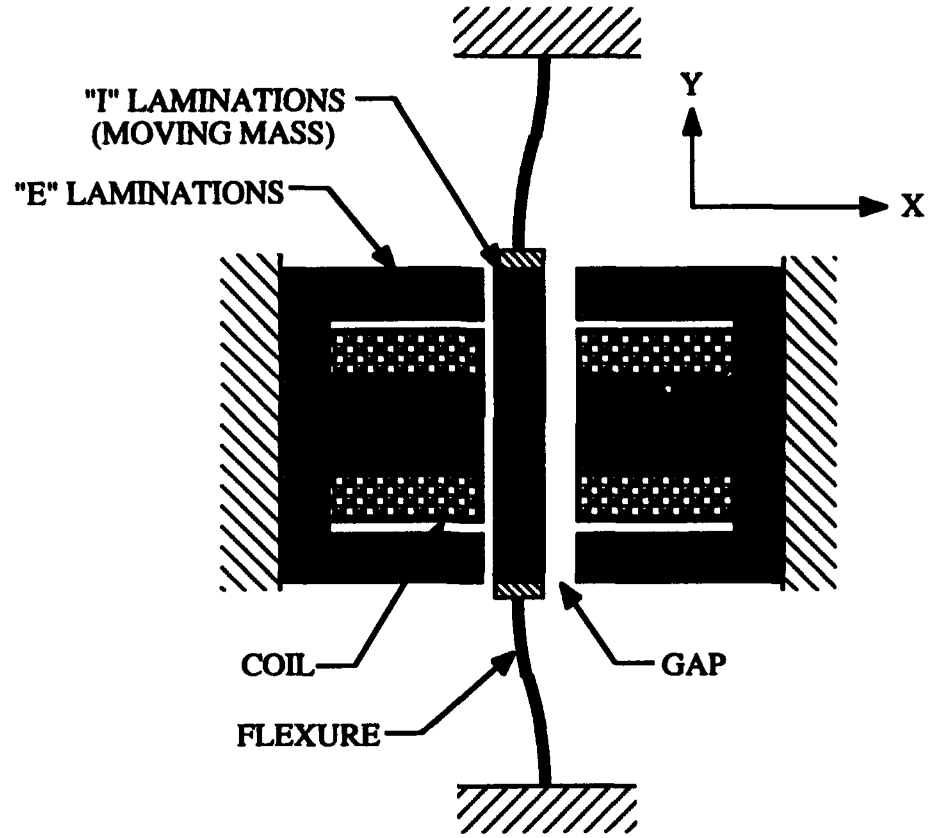

Figure 2: "Pull-Pull", Two-Electromagnet System with an Assisting Flexure.

As can be seen in Figure 3, another problem which must be addressed is the discrepancy between theoretical and actual electromagnetic forces. Because of losses which are functions of the laminations' material properties and the electromagnet geometry, the attainable magnetic field has a practical upper limit. If the attainable magnetic field has an upper bound, then the achievable magnetic force will also be limited. Work by Poovey, Holmes, and Trumper [1] has shown that the actual forces deviate substantially from the values predicted by Equation 2. To better characterize the behavior of a electromagnetic/flexure system, a simple prototype (similar to the system depicted in Figure 2) will be designed and constructed. The process of specifying the various electromagnet components (e.g., "E" and "I" laminations, wire size, bobbin size) is underway.

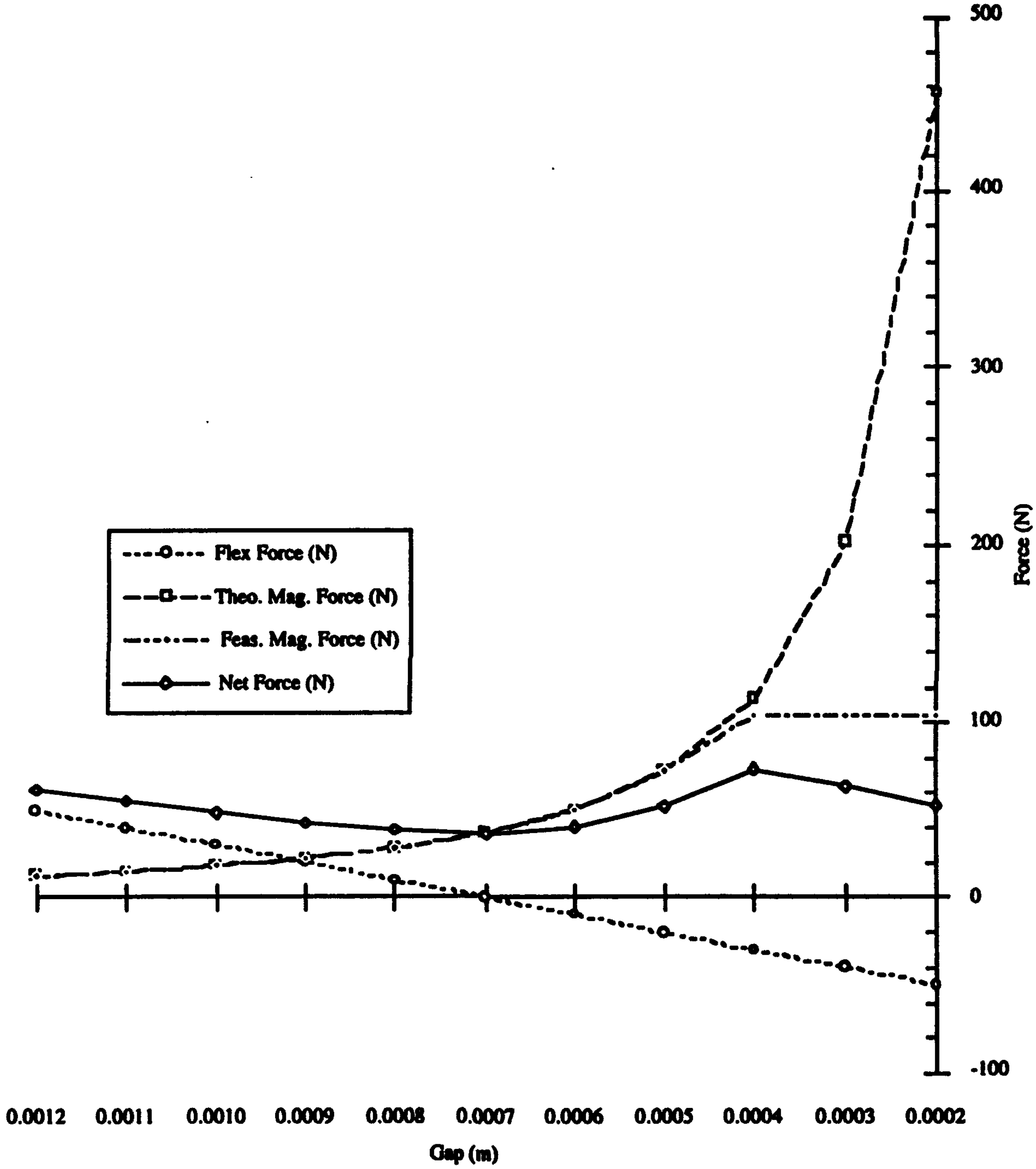

Figure 3: The Flexure Force, the Theoretical and Feasible Attractive Forces of the Right Electromagnet, and the Net Force as the Moving Mass is pulled from the Leftmost Position to the Rightmost Position.

References

[1] Poovey, T., M. Holmes, and D. Trumper, "A Kinematically Coupled Magnetic Bearing Test Fixture", *Proceedings of the Seventh Annual Meeting of the American Society for Precision Engineering*, October 1992.